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Reducing Insect Injury to Stored Corn

BY

W. E. HINDS, Entomologist.

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Reducing Insect Injury to Stored Corn.

W. E. HINDS, ENTOMOLOGIST.

IMPORTANCE OF PROBLEM.

In economic value for the Southern States, this problem is only second in importance to that of controlling the Mexican cotton boll weevil. The present interest in stored corn insect control is in some measure an outgrowth of the fight that is being made for better farming in the boll weevil campaign which involves the reduction of cotton acreage, diversification and rotation of crops, the increase of live stock production, etc. All of this means for one thing, more corn and longer storage for part of the increased crop.

Corn Production Possibilities in Alabama.—Within the past few years, the boys of the South, under the guidance of the Corn Club movement, have repeatedly demonstrated that the South can produce larger yields of corn per acre than perhaps any other section of the country, and withal can produce it more economically than any other section. Alabama can present several thoroughly well authenticated records that may challenge the world. In 1911 a fourteen-year-old boy produced over 212 bushels of corn on an acre at a cost of 8.6c. per bushel. This record for low cost in producing a yield of such size is likely to stand unsurpassed for a long time. In 1912, which was a good corn year, twenty Alabama boys produced an average of 164 bushels per acre at a cost of 16c.; one hundred and thirty-seven boys averaged 121 bushels each on one acre, and the 203 who received diplomas averaged 112.16 bushels at an average cost of 27c. In 1913, the climatic conditions were less favorable, yet thirteen boys produced over 150 bushels each and the largest Alabama Club record was 232.7 bushels at a cost of less than 20c per bushel. There is no longer any question that the South can raise her corn, the real question now is, can she preserve it from insect injury during storage so that she may steadily increase her production until she raises at least all that she needs and can profitably utilize in her home consumption? At the present time we need twice our present yield and this need is bound to increase greatly in the near future, for the South is apparently destined to become the greatest section in this country for increasing meat production upon the farm.

Insects Concerned.—There are several species of insects concerned in the injury to stored corn, and their relative importance varies in different sections. The most generally important of these species include two moths: The Indian meal snout moth (**Plodia interpunctella**) Pl. II, figs. 4-6, 8, and the Angumois grain moth (**Sitotroga cerealella**) Pl. II, figs. 1-3, 7; three or four small beetles known generally as enemies of stored products; the rust-red and confused flour beetles (**Tribolium ferrugineum**) Pl. I, fig. 8, and (**T. confusum**) which looks much like the preceding species; the saw-toothed grain beetle (**Silvanus surinamensis**) Pl. I, fig. 11; the square-necked grain beetle (**Cathartus gemellatus**) Pl. I, fig. 12; a larger black beetle called the cadelle. (Pl. I, fig. 7); and more important than all these put together in most of the territory within 200 miles of the coast through the South Atlantic and Gulf States and extending still further inland in Louisiana, Texas and through Mexico is the so-called rice weevil (**Calandra oryza**) Pl. I, figs. 1-6. This species is known so much more commonly here in the South by the name of "black weevil" that we think this common name should be generally adopted. It is this species, the black weevil, that we have been studying especially and to which we shall refer particularly in the balance of this bulletin. Fortunately, what is most effective for the control of the black weevil is effective likewise in reducing injury by most of the other species mentioned.

Loss in Seed Corn.—There are several phases to the question of loss caused by insects to corn, particularly during storage. This injury often affects seriously the value of seed corn in the South. Infested kernels are not likely to germinate at all, and if they do start, the growth of the young plant is likely to be weak. Seed corn that would appear to be only lightly infested, may give only about 75 per cent. to 80 per cent. of germination. See Pl. IV, fig. 6. This poor seed means often broken stands and weak or barren stalks which decrease yields generally.

Poor Storage Methods.—Beside this, the crop of early maturing upland corn is commonly very seriously injured even before it is stored, especially where allowed to stand in the field until frosts occur, and this injury is continued and multiplied during storage. Late matured corn, such as is commonly produced on the lowlands and river bottoms, is rarely seriously injured unless through being mixed in storage with more heavily infested corn. In the method of storage that is most common in the South, the corn is usually allowed to stand in the field until after frost occurs;

PLATE I—Black Weevil and Other Beetles Attacking Corn

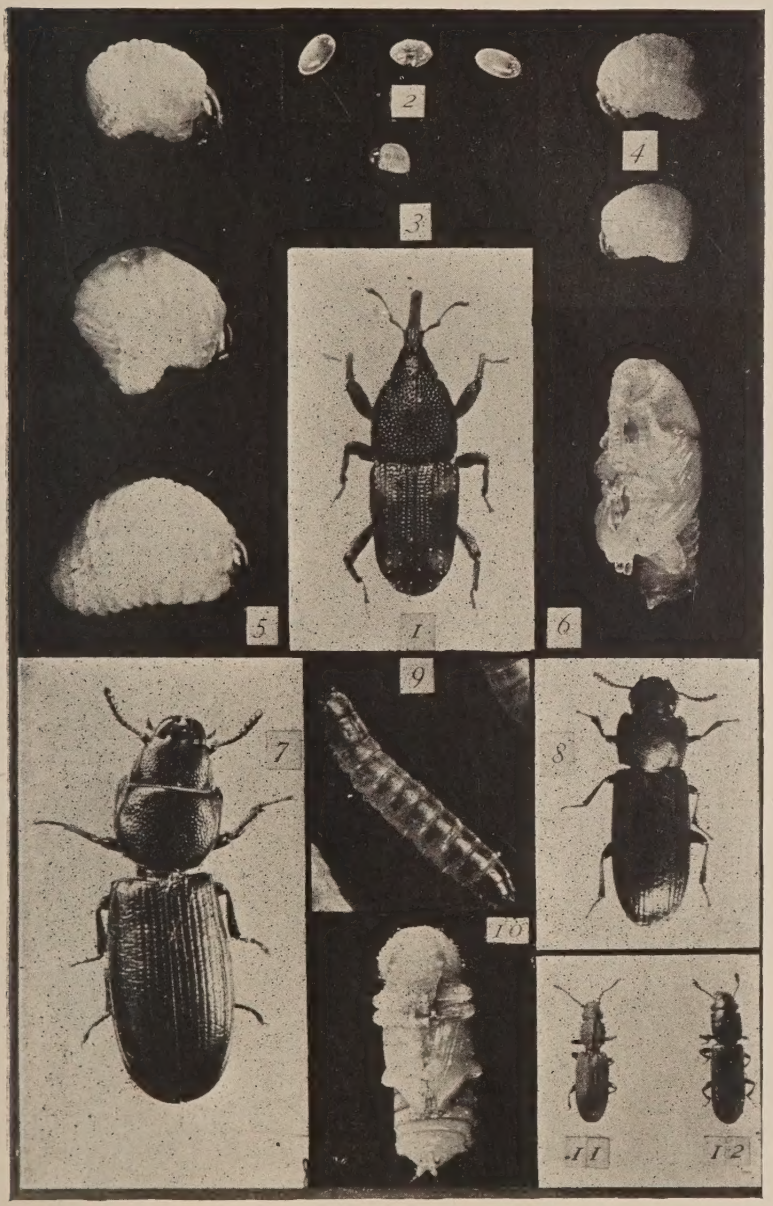

Fig. 1. Adult black weevil or rice weevil (*Calandra oryza*); fig. 2. Eggs; fig. 3. Grub or larva just hatched; fig. 4. Second stage larvae; fig. 5. Third stage larvae; fig. 6. Pupa; fig. 7. Cadelle (*Tenebrioides mauritanicus*); fig. 8. Rust red flour beetle (*Tribolium ferrugineum*); fig. 9. Larva; fig. 10. Pupa, same species; fig. 11. Saw-toothed grain beetle (*Silvanus surinamensis*); fig. 12. Square-necked grain beetle (*Cathartus gemellatus*). All figures much enlarged, original.

PLATE II—Grain Moths and Their Work.

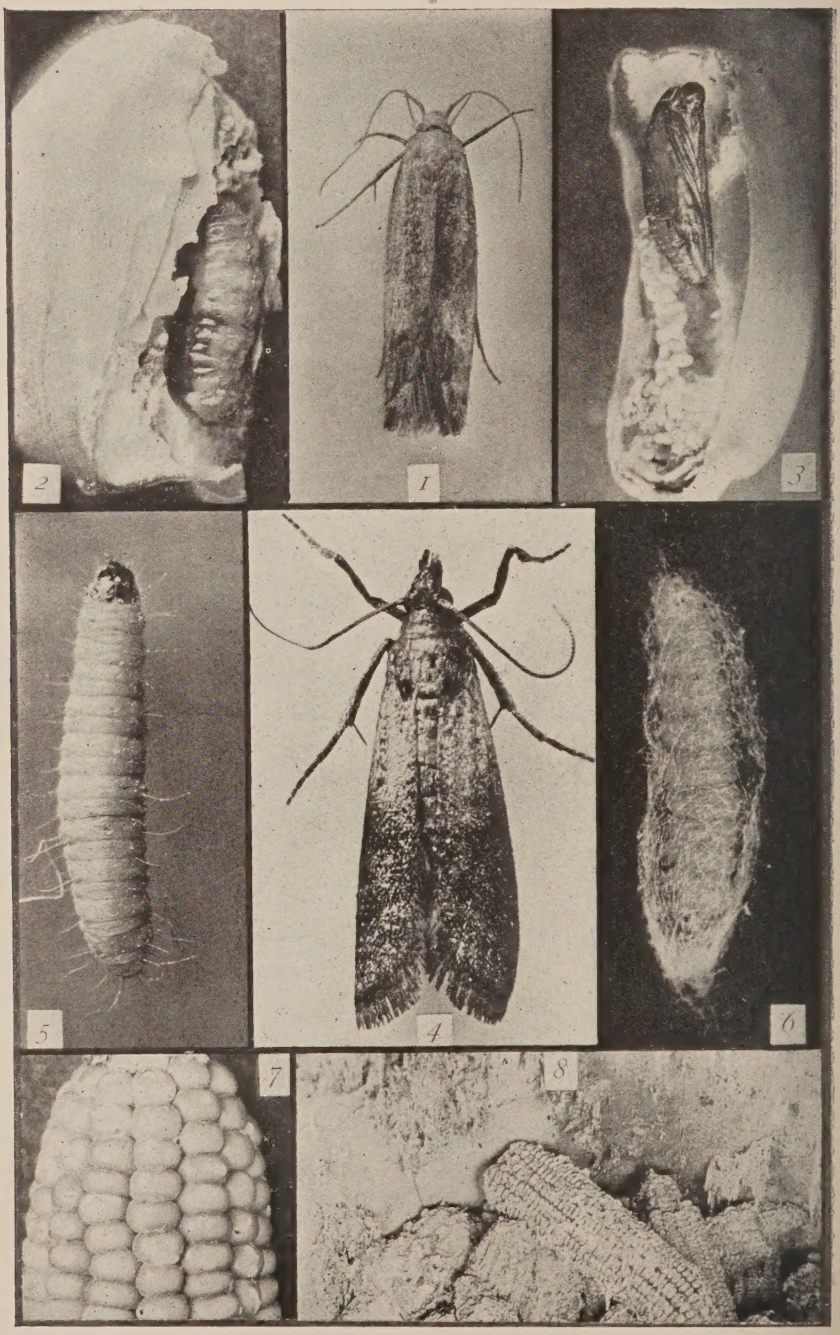

Fig. 1. Angumois grain moth (*Sitotroga cerealella*); fig. 2. Larva at work in corn kernel; fig. 3. Pupa of this species transforming inside of kernel; fig. 4. Indian meal-snout moth (*Plodiæ interpunctella*), fig. 5. Larva; fig. 6. Pupa, same species, transformation occurring outside of the kernel; fig. 7. Work of Angumois grain moth, note transparent caps where moths will emerge; fig. 8. Webbing done by Indian meal moth caterpillars.

then it is gathered, often when wet, with the whole husk left on and stored in very open cribs which are entirely unfitted for any fumigation treatment. The most common special practice for weevil control is to sprinkle the wet corn with salt or dust it with air-slaked lime, etc., as it is being stored. In these storage practices there are many elements that contribute to serious loss.

Waste in Storage Space.—There is a large waste in the storage space required. In studying several varieties of corn of widely different type, we have found that the space required to store corn that will yield one bushel of grain, is from three to four times as great where it is stored with the full husk on as is required for the shelled grain. An average of the results for several varieties required for 56 lbs. of shelled corn, less than six months old, about 1 1-9 cubic feet; for the same corn, ears husked 2.0 cubic feet; with "slip shuck" on, 2.5 cubic feet; and with the full husk on 3.6 cubic feet.

Corn Waste Estimate.—The waste in actual corn destroyed is a yet more serious item. The corn crop of Alabama for 1912 was about 54,000,000 bushels and the average yield was 18 bushels per acre. While this was only about three-fifths of what the State used, it is probable that something like 10,000,000 bushels were carried through into the early summer of 1913 and suffered extensive insect injury. Much corn is simply riddled by weevils before the end of November. Chemical analyses, together with weight determinations, have shown that in Central Alabama corn may lose fully two-thirds of its nutritive value during a year's storage. The loss in feeding value is even greater since it becomes so repellant to stock that horses, cattle and mules and even hogs may reject it. Poultry alone eat weevily corn with relish. It is probably conservative to estimate the loss to Alabama's corn crop at 5c. per bushel per month after November first for about one-half of our yield that continues in storage up to April first and for all the corn stored after that time. On this basis, Alabama's loss last year would reach close to $4,000,000.00 for nutritive value alone. Certainly, the protection of corn against a large part of such loss will pay a handsome return if it can be secured at anything less than an average cost of 5c. per bushel for the entire yield and certainly this can be done.

The net result of these most common practices in corn storage may be summed up in one sentence: Not only do they fail to reduce insect injury to the stored corn, but in

many ways they may even contribute largely to increasing that injury. The reasons for this conclusion will be shown briefly in succeeding paragraphs and from the many observations and experiments made we shall attempt to formulate some recommendations as to methods that shall have real, effective value in reducing insect injury. In the investigation of this subject various members of the department staff have assisted and credit is due especially to Messrs. W. F. Turner and J. A. Dew for their part in it.

SOME FACTS FROM THE LIFE HISTORY OF THE BLACK WEEVIL.

Winter Mortality.—Under winter climatic conditions that are normal for Central Alabama, there is no reproduction among the black weevils during about two months, ranging from the middle to last of December usually to about the middle or latter part of February. Immature stages then occurring in corn kernels develop very slowly, if at all. If unusually cold weather occurs, temperatures going to 20 deg. F. or lower, there may be a very large mortality among both adults and immature stages. When winter temperatures do not go below 20 deg. F. the total mortality may not exceed 10 per cent. from the beginning of November to the end of March. At the end of March, 1913, in examinations involving about 7,500 weevils, only 11 per cent. were found dead. Most of the corn ears examined were stored with husk on and thus probably retained all weevils that had died thereon since the infestation began in July or August of 1912.

It is certain that many weevils spend the winter in various places of shelter in the fields and woods outside the corn cribs, but from the enormous multiplication that is known to occur each spring in the cribs and in many other materials beside corn, it seems probable that the majority of weevil coming to the maturing corn are not specimens that have lived over in the field from the preceding fall, but rather are mostly the weevils that have developed in the cribs during the spring and early summer of the same season.

Spring Activity.—Oviposition is actively resumed in the corn bins with the advent of warm weather in spring, by March or April at latest, and the first real spring generation emerges usually sometime in May. Females deposit eggs at an average rate of about four per day in hard corn. Weevils leave the corn cribs and apparently go to the fields in large numbers during the warm days from the middle of

March to October. The height of this movement as shown by cage trapping tests appears to occur during July, by which time the second summer generation is out in the corn cribs and the corn in storage is then usually in very bad shape while that in the field is in condition for attack.

Field Breeding Begins as Corn Matures.—In the fields, however, we know of no spring breeding place. Weevils may be taken occasionally in the field and they feed upon a large variety of subjects, but normal breeding does not seem to begin out of doors until corn has passed its "roasting ear stage" and begins to harden up. When this condition of corn occurs, no matter what the date on the calendar, weevils seem to be ready for it and then, for the first time, come to the corn fields in large numbers. In several cases where most carefully studied, the weevils seem to have come most abundantly from the direction of the nearest woods. The earliest maturing corn—almost regardless of variety—attracts them in greatest number and, naturally, the ears that have exposed tips and loose, open husks are then the first and most heavily attacked (Pl. III, fig. 1). For a brief period, most of the weevils may be found upon the earliest maturing and most exposed ears on the plants scattered within perhaps 100 ft. of the outer edge of the field. Gradually they spread further inward until they are all over the field, but naturally the corn from the outer edges of the field and the poorly covered ears throughout the field will always contain more weevils than any other equal number of ears.

The eggs (Pl. I, fig. 2,) are laid in cavities eaten into the kernels and are deposited rapidly while the corn is in a partially hard or "gummy" condition. Eggs are not laid in the tassel as is sometimes supposed to be the method of infestation. The punctures are so small that they easily escape notice, but within these infested kernels the eggs hatch in about three days in summer. From them come the little white grubs (Pl. I, figs. 3-5,) which bore their way around in the kernels and reach their full growth in about seventeen days, the period usually ranging between fifteen and nineteen days in summer. The grubs then change their form (Pl. I, fig. 6,) to reach the weevil or full-grown beetle stage and a period of about a week more is required for this. The fully formed weevil then remains quietly within the kernel for several days more to harden before it cuts or eats its way out of the grain, as it does, leaving the small, round open holes that are a familiar sight to corn raisers in the South (Pl. III, fig. 4). The development of

the first fall generation, therefore, requires some five or six weeks after the corn has begun to harden or glaze.

These observations, together with the common experience that early-matured, upland corn is nearly always heavily infested, while late-matured river bottom corn escapes with practically no injury, point clearly to the feasibility of trap planting to concentrate weevils and of so handling our corn crop upon storage that heavily infested ears may always be kept separate from slightly or uninfested portions of the crop and the former treated for weevil control or fed out first while the latter may be carried through long storage without nceessity of treatment and with little insect injury.

FUTILE REMEDIAL PRACTICES.

In the course of our work we have endeavored to test fairly and carefully the various practices that are most commonly used for weevil control. Even the most careful and observant farmers are rarely situated so as to secure any really reliable information as to the exact results and value of such methods as they may have employed. All corn is usually stored in one crib, or in but a few dissimilar bins at most, and no attention can be paid to the separation of lots having different dates of maturity or other varying factors. All corn is likely to receive the same treatment and no adequate check is kept by which to measure the value, or lack of value, of remedial practices. Popular conclusions are, accordingly, but general impressions and liable to be mistaken.

We have referred to the common practices of allowing corn to stand in the field until after a killing frost, of storing while wet and with the husk on, of sprinkling with salt, etc., to prevent weevil injury. These, and many other popular ideas we have tested carefully both in the laboratory and in large out-of-door storage bins constructed especially for experimental work (Pl. IV, fig. 7) with the black weevil and we have found in nearly every case that they have practically no value in weevil control. A few of these ideas deserve specific mention.

Frosts Do Not Kill.—It is commonly supposed that by leaving corn in the field until after a killing frost occurs, the weevils on it are killed and that injury during storage is reduced accordingly. Ordinary killing frosts such as occur at the beginning of the cold season have no killing effect upon either adults or immature stages. Doubtless the motionless condition of benumbed adults on the cold morning following a frost has misled the casual observer into thinking them dead.

Husk No Protection.—Storing with the husk on is generally supposed to give more protection to the grain. On the contrary, it insures practically all of the weevils being successfully transferred from the field to the crib and in the crib the husk gives far more protection to the weevils already at work on the ears than it does to the corn.

Wet Corn Not Better.—The practice of storing while wet or of wetting as it is being stored, is supposed to facilitate a heating of the corn which will destroy the weevils and not injure the corn. It is apparently true that it is possible by a natural heating of a mass of immature or damp corn to produce a temperature that will accomplish this result and this does occasionally happen, but only in a very small fraction of one per cent. of the attempts is the desired benefit achieved. It is safe to say that up to the present time we do not understand the necessary coincident conditions of degree of moisture, volume of mass, and tightness of crib, etc., well enough to advise anyone to depend upon this heating for weevil control. The much more common effect of this excess of moisture in the storage bin is to soften the grain so that the insects can work so much the faster and to multiply the molds and other fungi growing therein.

Salt Increases Weevil Work.—The salting of the corn renders the husks more palatable to live stock, but on the other hand appears to increase rather than reduce the insect attack. It naturally gathers moisture from the atmosphere in every prolonged period of high humidity and thus renders the corn softer and more susceptible to attack both by insects and by fungi. A practical test of this treatment in our experimental crib (Pl. IV, fig. 7) in 1912-'13 with close observations as to the condition at beginning, during and at close of storage test, showed that the corn from the salted bin weighed the following July, only 0.9 as much for the same volume of husked ears as did the average of nine other tests having corn from the same field, stored at the same time, also with the husk on, but with no especial treatment. The corn from the salted crib was the lightest of any in sixteen tests and only 85 per cent as heavy as either similar corn that was fumigated with Carbon disulphide or "high life" at the time of storage or as untreated corn which had long, tight husk covering and no treatment.

Table I---Storage Test Resu

DATES OF STORAGE AND EXAMINATIONS 1912	Bin 8 Early corn husk on wet and salt		Bin 3 Early corn husk off untreated		Bin 7 Early corn S. L. H. on untreated		Bin 1 Early corn husk on check		Bin 11 Early corn S. L. H on untreated		Bin 15 Early corn S. L. H. on stored late	
	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils
September 20	25	587	40	58	40	1026	40	687	20	579	----	----
Average number weevils per ear	----	**23.5**	----	**1.5**	----	**25.7**	----	**17.2**	----	**28.0**	----	----
November 22	10	713	10	168	10	725	10	588	10	415	10	81
1913 January 9	10	519	10	61	10	580	10	335	10	394	10	160
Total fall exams	45	1819	60	287	60	2531	60	1610	40	1388	20	241
Average	----	**40.4**	----	**4.8**	----	**38.8**	----	**26.8**	----	**34.7**	----	**12.5**
March 13	10	850	----	----	10	1200	----	----	----	----	----	----
March 21	10	1003	20	396	10	985	10	523	10	970	10	324
June 13	10	1174	10	602	10	653	10	1696	10	1565	10	900
July 23	10	2030	10	811	10	1701	10	2124	10	1080	10	1035
Total spring exams.	40	5057	40	1809	40	4539	30	4343	30	3415	30	2259
Average	----	**126.4**	----	**45.2**	----	**113.5**	----	**144.8**	----	**113.8**	----	**75.3**
Total season exams.	95	6877	100	2096	100	6870	90	5953	70	4803	50	2500
Average	----	**72.3**	----	**21.0**	----	**68.7**	----	**66.1**	----	**68.6**	----	**50.0**
Lbs. weight equal volume of ears about ⅛ bus	21⅛		21⅝		22		22¼		22⅜		23⅛	

*October 25, 1912

attville, Alabama, 1912-1913

a 2 corn H. on ated		Bin 6 Early corn L. T. H. on untreated		Bin 10 Early corn L. T. H. on untreated		Bin 5 Early corn husk on CS_2 fum.		Bin 14 Late corn husk on unselected		Bin 4 Late corn husk off CS_2 fum.		Bin 12 Late corn S. L. H. on untreated		Bin 13 Late corn L. T. H. on untreated		Bin 9 Late corn husk off untreated	
Total number weevils		Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils	Number ears examined	Total number weevils
---		40	188	20	107	*40	*881	----	----	*30	*43	----	----	----	----	----	---
						*10	*804			*10	*75						
----		----	**4.7**	----	**5.4**	----	**33.7**	----	---	----	**5.**	----	----	----	----	----	---
26		10	155	10	205	----	----	10	0	----	----	10	22	10	0	10	1
75		10	271	10	151	----	----	10	13	----	----	10	3	10	4	10	3
101		60	614	40	463	50	1685	20	13	40	118	20	25	20	4	20	4
5.0		-	**10.2**	----	**11.6**	---	**33.7**	----	**0.6**	- --	**3.**	--	**1.3**	----	**0.2**	---	**0.2**
----		10	570	10	550	25	415	----	----	100	485	----	----	----	----	50	92
146		10	251	10	441	16	213	10	71	50	405	20	90	20	90	40	66
753		10	519	10	526	{ 6 { 10	49 616	10	340	20	147	10	409	10	153	10	201
419		10	874	10	1177	10	594	10	385	10	141	10	447	10	341	10	248
1318		40	2214	40	2694	67	1887	30	796	180	1178	40	946	40	584	110	607
43.9		----	**55.4**	----	**67.4**	----	**28.2**	----	**26.5**	----	**6.55**	----	**23.7**	----	**14.6**	----	**5.5**
1419		100	2828	80	3157	117	3572	50	809	220	1296	60	971	60	588	130	611
28.4		----	**28.3**	----	**39.4**	----	**30.5**	----	**12.2**	---	**5.9**	----	**16.2**	----	**9.8**	----	**4.7**
25		25		25		25¼		26		26½		26¾		26¾		27½	

Comment on Table I.—The general appearance and arrangement of the storage bin used in the tests detailed above, as is shown in Pl. IV, fig. 7. Some explanation of the table and comments on Table I, showing results of the tests may be in order. The arrangement of results as given is based upon the condition of the corn as shown by the weight of equal volumes of ears at the end of test period, July 23, 1913, which was practically one year from the time the weevil attack might have begun in the early corn. In the column headings are indicated the early or late maturity of the corn, the conditions as to husk covering and the treatment, if any was given. "S. L. H." in the heading means "short loose husk," and "L. T. H." refers to "long tight husk." The average number of weevils per ear is shown in heavy type: First, at the time of storage; second, for the three or four fall examinations that were made before mid-winter; third, for the three or four examinations made after mid-winter and called spring examinations, and, fourth, for the average for all examinations covering the entire season. It should be stated that the different bins were not all closely covered so that some movement of insects from one bin to another was quite easily possible and this movement is known to have occurred, especially from March to July. In a number of cases, as with bin 9, for instance, most of the weevils found therein late in the season were due to the spread that occurred during the spring from heavily infested adjoining bins. In some cases also with early corn stored with the husk off, as in bin 3, it is certain that the exposed grain served as a trap attracting moths particularly from adjoining bins and the poor condition of the corn in bin 3 was attributable to moths rather than to weevils.

Among the most important points shown by the table may be mentioned, first, the great difference in weevil work on early as compared with late matured corn. The records show about fifty times as many weevils on early corn up to mid-winter as on late corn. Second, the results from bin 8 would indicate that the practice of storing corn wet and salted is decidedly favorable to insect injury as this lot started with slightly lower infestation than some others stored at the same time, but weevil multiplication in this lot finally exceeded that in any tested. The final condition of the corn was the poorest in the 16 lots. Third, the value of husking is clearly indicated by the fact that the best lot of both early and late corn was stored without husk.

WEEVIL RESISTANCE IN CORN VARIETIES.

It is a matter of common observation that different varieties of corn grown side by side, with all planting, cultural and soil conditions similar, may vary greatly in their susceptibility to, or resistence to, insect injury. The two most important factors in producing this variation are generally comparative rapidity of development to maturity of the grain and the relative length and tightness of the husk covering. For several years we have been growing side by side a number of most promising weevil-resistant varieties that we could secure and compared these with commonly grown varieties which have been included in the variety tests at the Alabama Experiment Station.

Value of Husk Covering.—From our study of these varieties, we have become convinced that weevil resistance depends first of all upon the length and tightness of the husk covering upon the maturing ear (Pl. III, figs. 1-3). Where the tip is thoroughly covered and protected during the ripening period, even soft kerneled corns will suffer less from insect attack than will hard grained varieties having their tips exposed because of a short or loose husk. Length of husk is variable and exposed tips do not necessarily mean more fully developed or long husk imperfectly developed ears. See Pl. III, fig. 1-3. Long husks can be bred by selection in any variety. Hardness of grain does indeed retard the rate of work of the insects, but all varieties necessarily pass through a period between the roasting ear stage and full maturity when they are very susceptible to insect attack and will be so attacked if the husk is short or open so that the tips are exposed and if it also happens that the date of maturity is relatively early so that they may attract weevils before they have located and begun breeding elsewhere. Good husk covering and proper storage methods may entirely prevent the necessity for fumigation treatment. This is the aim of our work.

We consider large yield, sound grain, thorough husk covering and pendent ears to be among the requisite characters and would rank varieties principally according to their possessions of this combination of characters in largest degree. Work in breeding corn for these characters should give extremely valuable results in the near future in reducing insect injury during storage.

Promising Varieties.—Among the most promising varieties found to date are Experiment Station Yellow, (Pl. IV,

fig. 1), a variety under selection for many years past by the Alabama Experiment Station for weevil resistance. It has repeatedly stood high in yield. About half of its ears are now pendent and about 80 per cent. are exceptionally well covered. Another good yielding variety already widely planted, known as Whatley's Prolific (Pl. IV, fig. 2,) had about 90 per cent. pendent and 80 per cent. of well covered ears and this variety was attacked but very little in 1913. Among less well known varieties, several deserve mention and further study. A new variety known as Moyer's Prolific, supplied to us by Mr. O. H. Moyer, of North Augusta, South Carolina, showed up remarkably well in 1913, having on 75 plants, 164 good ears, of which 85 per cent. were pendent and 97 per cent. extremely well covered. There was almost no weevil work on this variety in the 1913 tests. Randall's Branch (Pl. IV, fig. 3,) and U. S. D. A. variety No. 181 were also unusually good, both in yield and in soundness of grain. Among varieties, not especially resistant, but which are widely planted, Hastings, Mosby and Marlboro Prolifics would rank quite closely together, while some large-eared varieties like Shaw and Henry Grady, while good yielders, have a large percentage of ears with tips exposed and the weevil infestation therein usually runs high even before time for storage (Pl. III, fig. 1). Work along these lines will be continued and it is quite possible that in other seasons different results may be obtained and other varieties may appear promising.

Effect of Date of Maturity.—While date of maturity is not really a natural factor in weevil resistance, it is an extremely important factor in its effect upon the severity of insect attack. It is a well known fact that early matured upland corn suffers far more severely than does the same variety grown upon river bottoms and maturing at a considerably later date. This difference does not depend upon any inherent difference in the character of the corn, but rests primarily upon the fact that the early matured corn—whatever the variety—attracts and holds the major part of the weevils so that there are few left to seek the later fields. In the early corn, also, there is a longer period in which to reproduce and multiply their injury before the corn is stored. Consequently, in January there may be an average of fifty or more times as many weevils in the early upland corn as in the late bottom corn of the same variety and

grown on the same plantation. Field experiments and observations show that we can, and should, take advantage of this extra attractiveness of early corn, by deliberately planting certain rows or plots to serve as a trap for the weevils and by concentrating them upon a small area, we can quite easily handle that portion of the crop so as very effectively and economically to reduce the insect injury in the bulk of the crop.

RECOMMENDATIONS FOR FUTURE PRACTICE.

Looking at the problem from the point of view of protecting the corn crop as it is produced and stored, we may mention some of the main points in a system that will largely reduce the attack by weevils and minimize loss during storage.

Seed Selection.—This should by all means be practiced in the field at the time of harvesting. Only at that time can proper attention be paid to several of the most important factors in corn improvement, such as the type of plant, height of ears, number of ears per plant and whether ears stand erect or hang down, etc. If obliged now to depend upon crib selection, and the corn still has the husk on, we would select ears havng tight husk covering in addition to other desired characters. (Pl. III, fig. 2.) We would advise breeding corn for large yields of sound grain rather than for the "show type" of ears.

Trap Rows.—To protect upland corn, we should at planting time, provide for a few rows to be planted two or three weeks earlier, or with seed of a more rapid maturing variety, so that they will mature earlier than the main crop and serve to concentrate the weevils thereabouts. These trap rows should be placed on the sides of the field and next to the woods, if any occur near the field. It has been found that weevil attack begins on the edges of the field and is heaviest on the side next to woods. From six to ten trap rows may be sufficient. Nothing else need be done to vary the culture or treatment of the entire field until about five or six weeks after the roasting ear stage has been reached by the earliest matured corn. At that time close examinations would show that most of the weevils in the field occurred on the ears of the few trap rows. Therefore, then gather immediately all ears from the trap rows. Leave the husk on in this case as it is our purpose first to remove as many as possible of the adult egg-laying weevils from the field, and, secondly, to prevent the spread of these weevils.

and their progeny in the first fall generation, from the trap rows into the main body of the crop. This trap corn may be fed out immediately or if it is to be kept for several weeks, it should be fumigated as soon as stored. The main crop may then be gathered at the most convenient time if weevils do not appear abundantly in it. But if weevils do become abundant, the sooner the corn is harvested and treated, the more insect injury can be prevented in it.

Harvesting and Storage Methods.—We realize that in Alabama there is a strong common feeling that corn should be stored with the husk on. A study of weevil occurrence in various sections of the State in the cribs of numerous farmers has shown that a few men have already become convinced that this practice is a mistake and are, therefore, husking their corn before storing it. A study of the results of storage experiments (Table I) made at Prattville, Ala., by this department in 1912-13 shows that in an average of four bins in which corn was stored with the husk off, there occurred on 510 ears, 5,475 weevils—an average of 10.74 weevils per ear. In an average of 12 bins stored with the husk on, there occurred on 942 ears examined, 41,147 weevils—an average of 43.7 weevils per ear. The same volume of corn from the lots stored with husk on weighed on July 23 (about one year from the time of its maturity) 24 7-32 lbs. as compared with 25 4-32 lbs. for that stored without the husk. It would appear that the value of the grain saved by husking would more than pay for the labor required.

Have the storage crib thoroughly cleaned and ready. For the main crop we would advise breaking the ears from the husk as it is gathered, thus leaving three-fourths, at least, of the weevils in the field. Have the wagon body fitted with a cross partition so that the slightly infested corn may be kept separate from that already quite heavily infested Or, if preferred, provide for the separation to be made as the corn is unloaded. Have a box fastened at the rear end of the wagon-body to receive the best ears from which seed corn may be sold and the seed for next planting may be finally selected. At the crib in which corn will be carried longest in storage, leave only the soundest corn. Never mix good and bad ears in the long storage bin if possible to avoid it. The many weevils that are shaken off into the bottom of the wagon should be swept out at some distance from the crib so that they will not be likely to find their way back to it. In these ways the storage period may be

PLATE III—Black Weevil Work and Protection Against It.

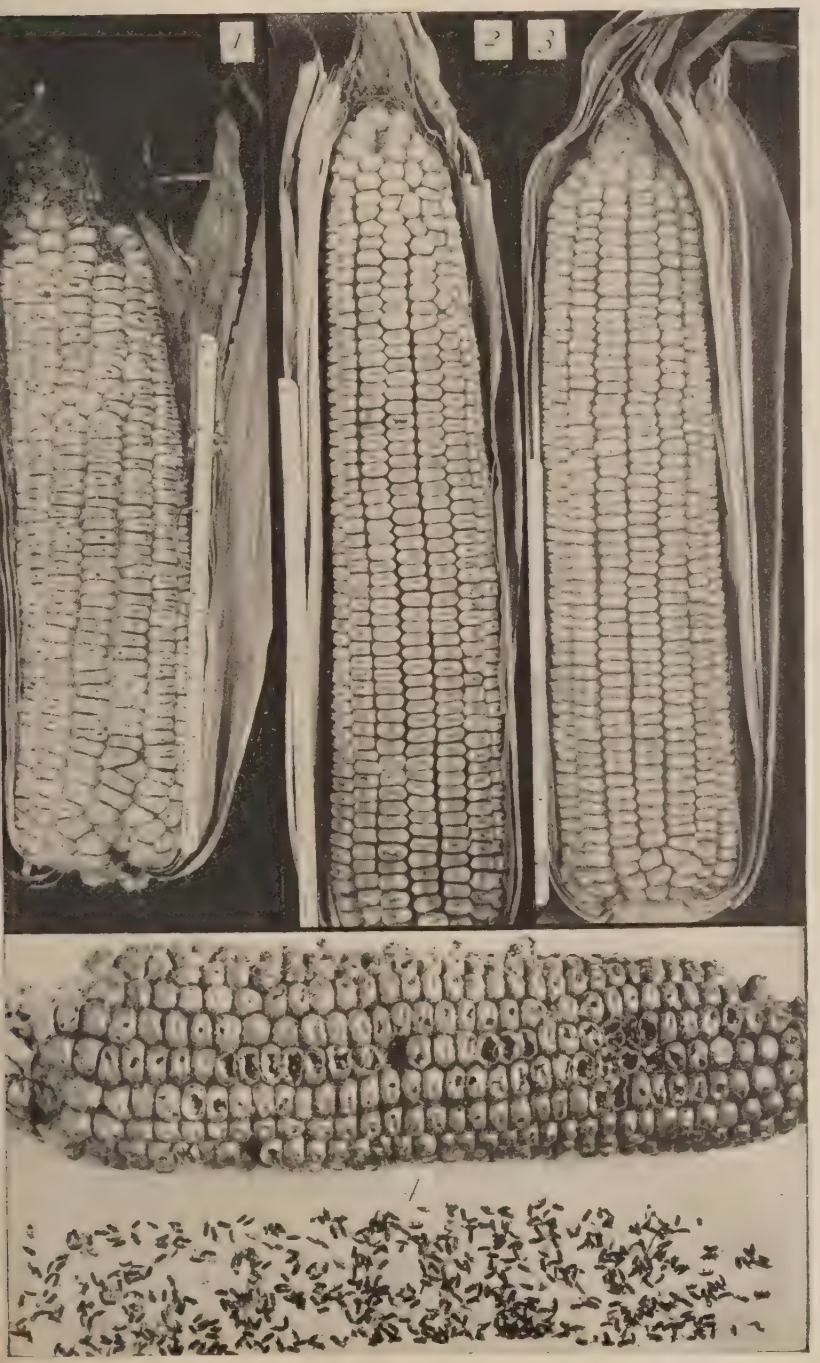

Fig. 1. Ear having exposed tip, showing condition at time of storage; fig. 2. Large, well-formed ear, also well covered; fig. 3. Another variety, still larger but well covered;

Fig 1. Exceptionally well-covered ear, Experiment Station Yellow; fig. 2. Well covered ear, Whatley's Prolific; fig. 3. Pendent ear, Randall's Branch; fig. 4. Early matured corn fumigated in fall, showing good condition following July; fig. 5. Early matured corn not fumigated, much injured following July; fig. 6. Black weevil injury to germination;

started with a minimum number of insects present and fumigation may be unnecessary.

FUMIGATION TREATMENT.

In many cases, especially with early corn, it will be found that weevils are abundant at storage time. Many ears may be "mealy" at that time and contain up to 400 weevils on an ear (Pl. III, fig. 1). Such corn should be so placed that it may be fumigated immediately and effectively.

Satisfactory and economical fumigation requires the use of a room or bin having unusually tight floor and walls as the vapors must be confined long enough to penetrate through the mass of grain and kill the insects. It requires at least forty-five minutes exposure to a very strong gas to kill the black weevil adults and the smaller brown beetles are still more resistent. Under ordinary conditions a killing atmosphere must be maintained for at least two hours to get the adult insects in corn. A still longer treatment will be required to destroy all insect stages within the kernels and prevent all further development and injury, but this can be done under favorable conditions. Much good can be done by using heavy doses of Carbon disulphide in an ordinarily tight room or even by treating a large mass of corn in the husk (several hundred bushels) in an open crib. This is because the corn mass itself acts as a retainer of the gas, holding it long enough to kill in the interior of the mass although it may not be effective on the surface and at the sides.

Making a Fumigation Room.—A tight room may easily be built especially for fumigation work and this will save much in reducing the amount of Carbon disulphide required. Ordinary matched flooring or ceiling is not tight enough for this work, but a room made as follows will do well: Board the room, floor and walls, with sized boarding, fitting as tightly as may be done. A heavy coating of tar at the points where rats and mice might gnaw through will help in keeping them out. Over this first boarding tack, or better, paste a layer of some heavy paper. A tough, hard paper such as is used in wrapping hardware, etc., is perhaps best, but tarred paper will answer also. Place the corner strips so that the middle of the strip fits into the corner, both around the floor and up the walls. Then lap other strips thereon, at least four inches, pasting the edges tightly together. Cover floor, walls and door in

this way and the ceiling also if it can be applied there readily. Next cover with a layer of rough boarding running at right angles to that first applied to protect the paper and break joints as much as possible. The paper, not the double boarding, is what gives the gas-tightness, so see that it is carefully applied. Have doors and windows close against paper bearings rather than against a porous felt.

For treating peas, beans, shelled corn, etc., a water-tight barrel makes a good container. The top may be covered tightly and conveniently by spreading heavy wrapping paper over and tying it closely around the top of the barrel.

Estimating Dosage.—Determine the number of cubic feet in the room to be fumigated, by multiplying its length by its breadth and this product by its height. Treat for the entire room and not merely for the mass of grain as the gas will diffuse through the entire space. Carbon disulphide dosage is usually stated in number of pounds per 1,000 cubic feet. The range would usually be from about 5 to 8 lbs. for an especially tight room such as has been described above, to about 20 to 25 lbs. for a moderately tight bin such as might be single sheathed with common flooring or ceiling. Larger doses are needed accordingly with small lots of corn. In actual practice determine how strong a dosage is called for by the condition of the room and the mass of the grain, then use proportionally as many pounds as the number of cubic feet bears to 1,000. For example: To treat a room 6x10x8 ft. with a dosage rate of 20 lbs. per 1,000 cubic feet, we would have 480 cubic feet or just about one-half of 1,000, and would, therefore, need 10 lbs. of liquid. For a room 12x15x10 ft. we would have 1,800 cubic feet and for a dosage rate of 25 lbs. we would need 1.8x25 or 45 lbs. of Carbon disulphide.

For treating peas, etc., in barrels, an average dosage of about one-half teacupful is sufficient if the top of the barrel be tightly covered.

Making the Application.—In making the application, level off the surface of the corn and prepare small holes about 1 foot deep by pulling out the ears, at intervals of 3 to 4 ft. apart each way. Divide the liquid to be applied among these holes. Begin at the side farthest from and work back toward the door. Pour the liquid directly onto the corn—it will not hurt it either for food or for seed—and fill in the holes immediately with corn to confine the fumes as much as possible.

Close the door tightly and quickly paste paper over the cracks around it. Leave the room closed at least 24 hours and no harm will be done if left indefinitely. Fumigation is much more effective during warm weather, partly because of the more rapid evaporation and partly because insects are then more active and therefore more susceptible to it. Never attempt to use Carbon disulphide when the temperature is below 60 deg. F. It is better to start the treatment at 10:00 to 11:00 A. M. rather than at night, both on account of having good light and also higher temperatures. A second and stronger treatment should be given if after a week or two it should appear that the first was not satisfactorily effective. Ordinarily, one treatment in the fall and possibly another in March or April will be sufficient to protect the corn. Prompt and thorough treatment is most profitable.

Carbon Disulphide or "High Life."—This is a heavy, volatile, ill-smelling liquid. It can be purchased in small quantities through any druggist. If needed in considerable quantity it can be secured at much less than usual retail prices by ordering from a wholesale druggist or directly from the manufacturers. A chemically pure grade is not needed in this work. A brand made especially for insect control known by the trade name of "Fuma carbon disulphide" is supplied by its manufacturer, E. R. Taylor, Penn Yan, New York, in lots of 50 lbs. or more at a very low price. It comes in steel drums and keeps in them until used. The Independent Chemical Co., 72 Front St., New York, N. Y., will also quote prices on orders for 100 lbs. or more.

Precautions.—Carbon disulphide liquid is not explosive or dangerous to handle, but the vapor from it, mixed with certain proportions of air, forms a gas that may be exploded by any kind of flame or even by a temperature of over 295 deg. F. without flame. It is, however, even less dangerous than the gasoline which is in common daily use in thousands of homes. Handle it as carefully as you would gasoline. Store in an out-house, where it will be kept cool and dry. It is not harmful to get the liquid on the skin and a good deal of the vapor can be inhaled before it will do any harm. If inhaled until one becomes dizzy, a few minutes deep breathing in the open air will quickly remove its effects.

Do not apply to corn while there is evidence of heating

in the grain and never allow fire in any form near the exposed liquid or where the vapor is at all strong. This includes especially lanterns, cigars, pipes, lighted matches, etc.

Value of Control Work.—The cost of fumigation will ordinarily be only a fraction of a cent per bushel. The prevention of insect injury through the planting of weevil resistent corn and through proper fumigation of corn, peas, etc., may easily have a cash value of more than half the value of the material treated or above 50 cents per bushel. It is not, therefore, a question of "the expense of control work," for it is already costing us in Alabama, millions of dollars more not to practice any control. It is a measure of real, true economy, stopping one of the big leaks in our farm economy. While it will take many years to effect a general change in our methods of raising, handling and storing corn in the South, it is certainly worth our while to do everything possible to save for this section a large part of an unnecessary insect injury that is now taxing our farmers directly to the extent of several millions of dollars annually and holding back rural development in other lines that cannot be valued in terms of money.